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114019 Understanding and Managing Causality of Change in Socio-Technical Systems III

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Abstract:

Understanding and managing for change is a central concern of design, commerce and societies. Well-intended interventions often lead to unexpected outcomes with significant implications for health, safety, security and prosperity. While considerable intellectual investment has been directed at quantitative and statistical approaches to understanding causality of socio-cultural system change, the complexity and indeterminate nature of underlying states and often nonlinear dynamics poses significant, if not, intractable measurement, computational, and interpretation challenges. As a result, a scalable and functional understanding of underlying causal dynamics of socio-cultural systems that can inform real-world interventions leading to desired outcomes remains elusive. What is needed in order to close the gaps resulting from the limitations of current approaches? In particular, what can be learned about underlying causal dynamics from case-based successes and failures? What are the fundamental constraints and best options for coupling multiple approaches and methodologies to "capture" real world scope, scale and complexity of dynamic events? What are the R&D options likely to push the states-of-the-art of understanding, prediction and intervention in terms of both control and design or re-design?

This research effort developed an informed perspective on the problem of understanding and managing causality of change in socio-technical systems. It leveraged interactions with a broad multi-disciplinary community of recognized thought leaders and identified, developed and rationalized specific science project objectives for causality and complex intervention research that broadens the research base in support of US national defense.

INTRODUCTION

The challenge of the problem of causality is that it is so pervasive and encompassing. The perception of relationships between cause and effect is a core property of intelligence that

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14. ABSTRACT
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informs decisions and actions, both anticipatory and responsive, to ideas and events in the world at large. From infancy, we observe, discover, and probe causal relationships in contexts of increasingly greater complexity. Causal assumptions, in turn, underlie our interpretations of history, culture, and religion and our prognostications of the future. Observing and controlling causal relationships is the basis of the reductionist scientific method and, within boundary constraints, it has enabled exploration, discovery, and extrapolation beyond the immediately sensible parameters of space and time. Orderly societies, commerce, and governance, in turn, rise and fall on the ability to anticipate and influence outcomes reliably in massively complex contexts.

With increasing complexity, ideas and events become interconnected in intricate and complex ways, making it increasingly challenging to establish causality through a given field. The linear way of thinking similar to a causal chain - A causes B causes C causes D and so on – breaks down in the presence of feedback and the presence of multiple interactions between pathways of cause or influence that can dynamically adapt and self-organize unexpectedly over time. As a result, traditional analytico-reductionist systems thinking, and approaches that presume order among causal relationships, make prognosis and influence much less clear and more uncertain.

On May 2, 2010, the New York Times published an article titled, "It's Complicated," describing how some of the world's toughest problems are spectacularly complicated. Almost all involve complex socio-technical systems that encompass interactions among multiple agents whose decisions and behavior are governed by intangible human variables such as faith, emotion, culture, confidence, etc. The problems include the management of economies, national healthcare, international air traffic management and safety, nation building and military effects-based strategy and planning and more. Unfortunately, the means to reliably "engineer" massively complex socio-technical systems is not mature and the cost of outcomes compromised by mishaps, unintended consequences, and other undesirable emergent effects directly reflects our limited practical understanding of complex causal dynamics and our inability to effectively anticipate and manage it.

Although considerable intellectual and financial investment has been directed at quantitative and statistical approaches to understanding the causality of socio-cultural system change, the complexity and indeterminate nature of underlying states and often nonlinear dynamics poses significant—if not intractable—measurement, computational, and interpretation challenges. As a result, a scalable and functional understanding of the underlying causal dynamics of socio-technical systems that can inform real-world interventions and lead to desired outcomes remains elusive. New conceptual and theoretical breakthroughs are most needed in anticipating and influencing causal outcomes.

MOTIVATION AND GOALS OF THE PROJECT

The current project emerged as an outcome of a series of discussions about the best strategy for raising the cumulative "impact" of the Air Force Office of Scientific Research's (AFOSR) research investment into socio-cultural modeling on our

understanding of the collective behavior of groups, societies and cultures. An approach that AFOSR knew would yield high returns involved funding multi-disciplinary collaborations between computer and social scientists. Such multi-disciplinary collaborations seem to push at the boundaries of understanding and practice in this problem area in novel and interesting ways. Hence, the notion emerged of organizing an interdisciplinary workshop where international thought leaders could interact while being pressed to identify the R&D options likely to push the states-of-the-art of understanding, prediction, and influence in complex socio-technical systems.

The project was designed to explore two basic assumptions. The first is that for domains that are very rich in behavioral and social phenomena, we need a better understanding of the nature of causality and causal dynamics if we are to refine our ability to influence and anticipate outcomes. We assumed there would be many concepts from mechanistic views of complexity and causality that could add value to the socio-technical domain. Overall, this bottom-up perspective presumes that the lack of a deeper understanding of causal factors and dynamics is a limiting deficiency reflected in most current approaches to socio-cultural modeling.

The second assumption is that there is much to be learned by observing “successful” expert practitioners who plan, predict and influence complex outcomes in systems design, finance and investment, medicine, enterprise planning and strategy, policy and military operations. Here, it is presumed that a better understanding of how experts infer and/or influence complex causal relations, at a better than chance level of consistency, could inform our understanding of causal dynamics and guide approaches to socio-cultural modeling. Hence, the workshop would stimulate interactions among subject matter experts from both theoretical and practical perspectives.

Key Theoretical and Technical Challenges

When designing the workshop, we first identified key theoretical and research questions relating to understanding and influencing causality of change that could be used to challenge workshop participants and focus discussions. The questions were binned into four categories that, in turn, also provided an organizing framework for the workshop: (1) dynamics and context, (2) methods and tools, (3) prediction and influence, and (4) management and control. The questions are listed below.

Dynamics and Context

- What can be learned from patterns of causal relationships that underlie a system, i.e., tipping points, pinball effects, etc.?
- Contrast the nature of causality in the realm of ideas versus the physical world. How could these interact and influence the causality of change in complex socio-technical systems? How do socio-technical systems evolve and transform?
- What are the drivers and moderators of change and stability?
    - What are the underlying causal dynamics that reflect and promote change and how do these vary with scale?

- How are causal dynamics determined by the nature of linkages and architectures of teams, groups, organizations, enterprises, and societies?
- What principles govern event propagation and emergence in socio-technical ecologies?

Methods and Tools

- How can we overcome the limits of current analytic, empirical, and modeling options for characterizing, studying, and understanding the etiology and dynamics of change in complex socio-technical systems?
- To what extent can multiple approaches be “viably” federated and/or made interoperable to support inferences about current vs. alternative or possible future states of complex socio-technical systems? This encompasses multiple sources of descriptive and prescriptive data from field work, stories, intelligence, models, surveys, ethnographic analyses, and case studies.
- What are the best means for characterizing and understanding the impacts of interacting multi-factorial causes and/or bi-directional causal chains?
- What are the differences between causality in the realm of ideas and causality in the physical world with respect to the methods and tools needed to understand their influence in the context of complex socio-technical systems?
- How can fundamental R&D in behavioral and social sciences provide value to understanding or influencing causality in a complex world?

Prediction and Influence

- How can the effects of context on the nature of change be understood, addressed, and realized, when considering the following systems?
    - Public vs. private systems
    - Products (e.g., airplanes) vs. service (e.g., healthcare)
    - Domains, i.e., military, manufacturing, healthcare, power (Smart Grid), etc.
- Design and intervention: Can understanding and knowledge of causal dynamics and “influential” contributors be used to affect desired outcomes in terms of control, design, and re-design?
- What are the implications of dynamics and context for the design of interventions or transformation of cultures, emotions and attitudes, beliefs and ideologies, organizations and enterprises?
- To what extent can such interventions promote changes of individual, group, and organizational behaviors?

Management and Control

- Can understanding and knowledge of causal dynamics and "influential" contributors be used to bring about desired outcomes?
- Are some people better at perceiving causal relationships, inferring the derivative products of complex influences and interactions and constructing and adaptively executing change strategies to influence outcomes?
- What can be learned about causal dynamics and managing complexity from successes and failures in real world interventions and practice?

From Workshop to Participant Selection

Our broad strategy was to identify and assemble an inter-disciplinary group of expert researchers and practitioners across a spectrum of the domains involved in both understanding causality and influencing complex outcomes. The workshop was a modified sandpit design where participants could easily mix and form productive relationships that could lead to new and novel insights. The theoretical and technical challenges listed above were used to attract and solicit interest from "candidate" participants from whom the final workshop participants were selected. Selected participants were, in turn, invited to contribute papers that reflected their perspective of the problem domain. Those papers are now the chapters that comprise this volume. Hence the project was composed of the design of the workshop, the workshop itself, the workshop proceedings and outcomes coupled with this archival publication.

Participants were selected so as to achieve a good mix of domain expertise, cultural perspectives, and sage thought-leaders vs. "Young Turks" in the final group to assure stimulating and productive interactions. Participants were selected from nine countries (Australia, Brazil, Japan, Norway, Netherlands, Philippines, Singapore, United Kingdom and United States). Table 1 lists eight domains reflecting the disciplinary roots and affiliations of participants. Table 2 shows nine self-reported domains of current expertise and practice. Table 3 lists eighteen specific research areas in which participants were engaged during the timeframe of the workshop.

• Behavioral and Social Sciences	• Engineering
• Computer Science	• Physics
• Information Science	• Philosophy
• Mathematics	• Law

• Systems Engineering and Design	• Statistics
• Human Cognitive Performance	• Philosophy
• Modeling and Simulation	• Complex Networks
• IT and Healthcare	• Law
• Management Science	

• Philosophical explanation of change	• Quantitative understanding of influence
• Bi-directional causal relationships	• Knowledge management and decision support
• Understanding social systems	• Complex system design and design goals
• Emotions, beliefs and perceptions as determinants of change	• Designing interventions in complex social systems
• Causality and dependency in n-dimensional networks	• Effective complex systems applications
• Human-Computer integration	• Technological innovation/ diffusion and its social effects
• Understanding causation and predictability in contexts	• Unintended consequences
• Causal reasoning	• Enterprise Transformation
• Understanding complex natural, artificial and social systems	
• Harnessing change in everyday contexts	

Participant Perspectives Surveyed

Just prior to the workshop, participants were surveyed as to what they viewed to be the key research challenges for understanding and influencing the causality of change, from

their disciplinary perspective. The responses were detailed and they provide valuable insights into the views of participants prior to their interaction at the workshop. An overview of the survey findings is presented below, grouped into three categories of interest: people, design and phenomena.

People

Participants raised many challenges relating to how people understand causality, and noted that differences between people need to be understood better. For example, why do some people reason using simple, linear causation whereas others invoke systemic causation? When we learn something new, or change our mind about something, how does it change the structure and functioning of our brains? Does the mental process of “changing one’s mind” correspond physically to the process of switching between attractors in our brain? Would a complex systems perspective centered, for example, on self-organizing, attractor neural networks be helpful in ordering our thinking about how internal psychic and neuro-dynamic processes cause people to reason and behave in one way or another?

Most models of causal reasoning have troubling representing cyclic causality—systems that involve loops of cause and effect among the relevant variables. Yet cyclicity is not only common but also pervasive. Two questions arise: 1) Are human cognitive systems capable of effectively representing such systems and, 2) If so, how?

Further challenges relate to people’s awareness of their success or otherwise at understanding causality. How does an internal observer/participant of/in a system “know” when the efficacy of a representation is breaking down such that there is a need to revisit broader messages such as stories and compressions? How do unrecognized affordances gain ontic status?

Understanding how causality varies also depends on culture; for example, Western versus European, Asian or Middle-Eastern (to name just a few) cultures. Understanding the role of geography and the role of population heterogeneity in the causality of change are important. Knowing how “repeatable” the causality factors are in future explanations/situations is also important.

Participants noted that the increasing demand for certainty in communities, enterprises, and institutions largely goes unchallenged. The unrealistic expectations that follow lead to distress that could be avoided if the givens and realities of the world were more honestly acknowledged. A better understanding of the causality of change would help us express more clearly the degrees of uncertainty and unpredictability in the world, so that professionals and communities could formulate and implement more appropriate policies, strategies, ways of working, and regulatory regimes.

A better understanding would help business people focus on complex causal issues and make structural changes necessary to affect long-term change. It would also help them explain complex causal relationships, structures and dynamics to people who believe that successful change can be instantaneous and not part of a relatively rigorous learning and

testing process.

An important point is that none of the enterprises we address can be directly changed in any wholesale way. We have to use our macro understanding to identify tipping points where seemingly small changes, that key stakeholders will embrace, will subsequently precipitate wholesale change. The challenge is identifying such high leverage small changes.

Design

Participants noted challenges rising from complex causal relations in a variety of different domains, with particular concern for how the design of, and intervention in, such domains might be supported.

For example, well-intended interventions are rife in traffic systems, often to address the physical constraint of high-volume traffic. Prediction of possible outcomes is challenging, mostly because people in traffic are agents that adapt to new rules. The same challenge with regards to prediction of possible outcomes in response to “new rules” is also present in fisheries.

In health, the design of effective electronic prescribing systems and health IT systems is challenging as it must take into account the cognitive, social, and organisational interactions between humans and technology

In military operations, comprehending complex causal relations is useful in the design of decision support systems for the tactical, operational, and strategic levels

The law tends to deal in binary concepts because dyadic decisions must be made by courts, such as “proved” or “not proved”, whether the cases be criminal, civil or administrative matters. A key challenge is to afford justice, especially to plaintiffs in civil matters, but without unduly burdening defendants with liability for conduct that at the time it was engaged in could not reasonably have been foreseen as risky, or where the outcome cannot be proved on the balance of probabilities to have caused the later status of the plaintiff. Thus, both factual causation and scope of liability issues arise, the latter of which involves questions of often poorly articulated policy in differentiating between influence and cause. Inevitably, blameworthiness plays an important role, as do constraints upon what can be proved and what cannot. The challenge for design in such cases is to create a legal system that deals fairly with attributions of causation.

Phenomena

Some participants also noted challenges rising from the concept of causality itself. An overview of some comments follows.

It was noted that the notion of necessity has deep roots in the philosophical thinking of causation. Causation appears to be highly context-sensitive, but few existing philosophical accounts provide an adequate account of the role of context in causation. Because of the extreme context-sensitivity of causation, the presence of a cause cannot

guarantee the presence of a predicted effect: any tiny change to the context may alter the predicted outcome. We need to understand how a non-linear composition of causes might work. Unfortunately, most scientists want full predictability and necessity when they deal with causation.

Strong correlations between the elements of the system, long memory, and hierarchical dynamical/geometrical structures are basic ingredients of complexity. However, the precise necessary and sufficient conditions for using, for a given system, the non-additive entropy and its associated non-extensive statistical mechanics remain to be established.

One participant noted that the causality of change can be studied using the same framework that we use to study systemic risks. When a risk materializes, it does so in an idiosyncratic way so that its consequences are hard to predict. Some risks are systemic, in that they have a permeating effect that challenges the integrity of a whole system. Although quantitative and statistical approaches to understanding systemic risks are available, the complexity of the underlying states pose significant challenges. As a result, understanding the underlying causal dynamics of risk becomes essentially the same as understanding the causality of change oinf socio-technical systems.

It was also noted that investigators can confront combinatorial problems when reasoning about causality. It is well known that agglomerated networks, regardless of the degree of coupling, pose significant and unique problems relating to aggregation bias. Tying in the inherent uncertainty of virtual networks, like ad hoc social networks, one rapidly comes face to face with a high-order combinatorial problem. This is the most challenging area of network analysis since it goes to the heart of network semantics, which is where the “high payoff” of the semantic web resides.

A key concern is influencing future events. One participant described the problem as identifying the critical points in a trajectory of events to for intervention, so as to influence/reshape the trajectory, the time-cost tradeoff and the interaction between different trajectories. In this case trajectories could range from trajectories of a social system to aircraft trajectories.

The major challenge of investigating the discourse around climate change is to understand the interactions over time of science, government, industry and media/technology.

Workshop Organization and Process

The Workshop took place on the Gold Coast near Brisbane, Australia on February 15-18, 2011. Table 4 shows the organizing framework of the Workshop. Participants were assigned to one of four working groups (Dynamics and Context, Methods and Tools, Prediction and Influence, and Management with Uncertainty) each of which was focused on the key theoretical and technical challenges outlined earlier.

The members of working groups were encouraged to self-organize and to narrow or broaden the stated challenges as necessary, in order to capitalize on the experience and

perspectives of the group members. The four working groups progressed through a series of three working sessions over the course of three days. Session 1, the “Cognitive Mixer”, was a baselining exercise where group members could introduce themselves, present their perspectives, and build relationships. Session 2, “Transformative Concepts”, promoted divergent thinking and challenged the group to push past the limitations of current ideas, concepts and/or strategies in the domain. Session 3, “Research Challenges”, promoted convergent thinking and challenged the group to identify and describe R&D options likely to push the states-of-the-art of understanding, prediction and intervention in complex socio-technical systems?

Following each working group session, all participants met in a plenary session to share and advance their ideas for going forward. The intent was to facilitate self-organization, energetize interactions and value outcomes. The next section represents selected insights that emerged from discussions in each of the working groups.

Table 4. Organizing Framework

Workshop Structure

	WORKING GROUPS			
	DYNAMICS & CONTEXT	METHODS & TOOLS	PREDICTION & INFLUENCE	MANAGEMENT with UNCERTAINTY
Session #1: COGNITIVE MIXER ***(Baseline)***				
Session #2: TRANSFORMATIVE CONCEPTS ***(Divergent)***				
Session #3: RESEARCH CHALLENGES ***(Convergent)***				

WORKING GROUP DISCUSSIONS

Dynamics and Context

Multiple disciplinary perspectives drove a need to find shared definitions for “system”, “socio-technical”, “causality”, “context”, “events”, and “change”. Overall, the following was agreed.

(a) Systems are comprised of many interrelated parts. However the group remained challenged by distinguishing between “complex” and “complicated”.
(b) People and technology are intertwined in socio-technical systems (STS) and STS exhibit intentionality and free will with potentially differing or competing interests.

(c) Multiple types of causality are possible (e.g. different causal questions with different types of answers, multi vs. single cause, etc).

The metaphysical nature of ‘cause and effect’ was discussed in terms of granularity, additivity, sequence, directionality and context. Context itself was differentiated with respect to connectivity, boundaries, part-whole relationships, temporality, etc.

The transformative issues raised were concerned with understanding the relations, interactions and influence of systems within systems (i.e., embedded systems). A sub-system was defined as having more connections within itself than connections going outside into the larger super-system (neighbourhoods/interconnectedness).

Defining and identifying change itself was an open question for discussion. For example, the group addressed whether reality is experienced as a series of discrete events or as a continuous stream? Multiple type of change were identified and discussed, including drastic change, pinball effects, unintended/unanticipated consequences, resultant/causal changes, structural changes, transparent vs opaque changes, etc.

Drivers of change discussed included urgency, “crisitunity” (i.e., crisis and opportunity), opportunity, and randomness.

A case study was used to ground and focus the discussions. The topic was the health care IT domain. The group selected it because it is a complicated, in the sense that adverse events are caused by a convergence of factors rather than by single events. This was developed into a mini-proposal on “Privacy, Threats and WikiLeaks” by the group and is described in greater detail below.

Methods andTools

Improved methods and tools are particularly needed to aid the visualization of possible future trajectories of a complex system and the determination of the consequences of various actions or events in order to support decisions about possible interventions. However, this also requires a greater understanding of causal dynamics and the fidelic means to simulate and assess the potential roles of tipping points, pinball effects, lynchpins, pawns, etc.

Several methods and tools became a focal point for discussion by the group. Of these, Namatame’s Network Analysis is discussed in Chapter 7 and Kondraske’s General Systems Performance theory is described in greater detail in Chapter 13. A mini-proposal was developed on the “Sociotechnical System of RPV/ISR Platforms” which is described in greater detail below.

Prediction and Influence

The core question for this group was whether or not prediction was possible as distinct from abduction, i.e., educated guessing. The core challenges for prediction are knowing whether all the influencing factors and context are accounted for, knowing whether there are bi-directional effects, and judging the extent of free-choice effects associated with

living organisms, among other contextual challenges already described in the above discussion of Dynamics and Context.

In general, the group concluded that causal tendencies, rather than outcomes, are predictable and then attempted to describe the limits of our ability to predict tendencies. The group also pointed out that not everything in the world is complex and that science has done a pretty competent job making viable predictions for many simpler effects in the engineered world.

The group proposed an interesting concept for an exploratory game designed to help people make or not make decisions based on the perceived value of possible outcomes. The “Emergence Machine” was developed as a mini-proposal and it is described in greater detail below.

Management with Uncertainty

The discussions by this working group were centered on producing prescriptive guidelines or heuristics for developing management strategies for low probability, high impact events. The group identified some principles for dealing with ambiguous situations. These principles include:

- Structure for emergence – conditions for change
- Ecological approaches, obliquity – managing for serendipity
- Inefficiency as a route to effectiveness
- Fail early, often and inexpensively
- Theory-shaped practice – but working with a sound theory (chef vs. recipe follower)
- Self-forming, task teams working across silos to build network density

An emergency disaster relief response scenario, “Floods, Fire, Plague, Pestilence and Boils” was proposed and is described below.

CONCLUSIONS AND IMPLICATIONS

The pre-workshop survey responses and the results of the working group discussions suggest some overarching observations. First, different disciplines have different perspectives, often very different, on complexity and causality. In other words, all the puzzle pieces do not necessarily belong to the same puzzle. Second, people involved with real world problems have rather different views from theoreticians addressing abstractions and/or simplifications of reality. It is very difficult to approach the full reality of complex socio-technical systems with a purely axiomatic approach.

Despite these differences – or perhaps due to these differences -- creative insights and ideas emerged from synergies across varying perspectives. Nowhere was this more evident than when groups having disparate perspectives attempted to develop an integrated formulation of a research problem and a recommended approach to this research. An outline follows of the seven research proposals developed at the workshop.

The Sociotechnical System of RPV Platforms

The introduction of armed remotely piloted vehicles (RPVs) has generated several unintended effects. There is a psychological disconnect brought about by the ‘normal’ home environment alongside the ‘non-normal’ combat environment. There are issues associated with the integration of large numbers of directly and indirectly controlled RPVs. There are also trust issues and consequences of data and information both on and off platforms, i.e., the ‘many hands’ problem.

Classic ‘task analysis’ has proven to be an insufficient method to determine existence of behavioral and performance patterns. Cognitive work analysis, on the other hand, offers the possibility for exploring a wide range of interventions (change conditions), risk assessments, or performance modeling and measurement. A better understanding of the stresses and unintended consequences of remote warfare could inform distributed information gathering, analysis, decision-making and authority to commit violence; needed skill levels of operators, analysts, and commanders in this new warfare environment; and the risk characteristics of the RPV sociotechnical complex system. Such an understanding would inform investment in new tools and methods that could have payoff in other systems, both military (e.g., urban warfare, counter-insurgency) and commercial (RPV air cargo, passenger aircraft)

Sociotechnical System of Veteran TBI/PTSD

Veterans who suffer from traumatic brain injuries (TBI) and/or post-traumatic stress syndrome (PTSD) return to a world that is full of complications. Time to diagnosis can be years, and effective treatment often continues over a lifetime. Unemployment and relationship conflicts are common; homelessness is increasing. Chairman of the Joint Chiefs of Staff Admiral Mike Mullen said, on National Public Radio, that there are 50,000 homeless veterans and it will get much worse

This proposal advocated a model-based approach to understanding this complex sociotechnical system that would enable an exploration of a wide range of interventions to manage it. The idea was to explore computationally many alternative interventions and empirically validate the apparent best choices. Of particular importance for these explorations would be alternative policy incentives and inhibitions, as well as alternative means for empowering patients.

Floods, Fire, Plague, Pestilence and Boils

State emergency services are inevitably involved in disaster relief. Little or no evaluation is conducted on the alternative role of military forces in disaster relief. Indeed, evaluation of the overall emergency response is often clouded in politics. Existing relief enterprise structures may need a paradigm shift. Traditional methods of inquiry may be inadequate for exploring this shift. A large-scale grass-roots data collection project may yield new perspectives.

This proposal articulated a narratives-based approach to emergency response that it was argued will yield insights not produced by previous initiatives. The technology exists to

capture and classify these stories – both micro-narratives and fitness landscapes. Multi-country case studies were proposed to provide a point of comparison, including Victorian bushfires, Queensland and Victorian floods, and the mine collapse in Chile.

Privacy, Threats, and WikiLeaks

How does the increasing ubiquity of health IT change the perspectives and attitudes of people on privacy and data protection and what are its legal, policy and systems consequences? In particular, what are professionals reading in hand-offs? Do they see a sign-out sheet? Is there a list of actions, a diagnosis, and perhaps a causal model of the patient?

What should be the institutional procedures for handing over information? Flexibility is essential, but might there be “black swans” that opportunistically take advantage of everybody. Privacy goals must respect demands of professionals yet be effective with respect to the professionals understanding the state and prospects for the patient. This proposal would explore the consequences in terms of patient care, potential unintended side effects, IT design, and changes over time.

Transplexity Guide

The goals of this proposal included advancing an understanding of how to develop, foster, and communicate 'complexity-aware' behavior in practice. This would involve (1) fostering the ability to dynamically transition behavior as circumstances require, (2) being able to judge appropriateness such as which concepts and techniques suit the changing context, and (3) developing underlying 'complexity-worthiness' which would enable the above to be achieved.

To achieve these ends, the proposal advocated developing a pragmatic approach to working with ambiguity, based on insights from complexity science, experience, and commonsense that would enable practitioners (e.g., in NGOs) to judge appropriateness i.e., select and use tools and techniques for influencing change, make the transition to transplexity ways-of-working, adjust 'complexity-worthiness' as circumstances require, and sustain relevant real-world change in practice. The intent was to make this body of knowledge 'real-world-ready' through case studies and proof of concept 'trials' and to develop techniques for communicating the approach, perhaps in terms of a Transplexity Guide, in a yet to be determined form.

In Search of an Emergence Machine

This proposal was premised on the notion that prediction is often impossible, except perhaps for predicting general tendencies. The importance of context is often a limiting factor. Thus, new tools are needed to enable prediction for complex systems. The brain was noted as a complex adaptive system, with its plasticity, rigidity, and causal history. This led to the idea of developing an exploratory game that would include the “physics” of both the world and the humans within it. Players could manipulate their way in the world as well as the world itself. The game would be educational and help people to make decisions. More to the point, it also could serve as a prediction mechanism. The

behaviors and consequences that emerge in the game provide a form of prediction of what would happen were the simulated situation to emerge in the real world.

Causality in the Realm of Ideas

This proposal focused on how the causal dynamics of ideas might be linked to the causal dynamics of physics. Questions addressed include whether "new" ideas emerge and consciousness arises from neural dynamics. Also considered was whether ideas and innovation could be predicted from neural dynamics. This led to consideration of how the power of an idea might be measured and predicted. Types of ideas discussed included innate, concrete, and abstract ideas, as well as ideas as systems, e.g., religion as a system of ideas. Power was conceptualized in terms of influence and persuasiveness. Why some ideas go "viral" but others do not was considered. The overarching notion was to research how ideas share characteristics of complexity. Are ideas adaptive, resilient, robust, and self-organizing?

Implications

The research implications of the workshop deliberations and the body of knowledge provided in this book are illustrated by the summaries of the seven proposal concepts discussed above. These are not traditional research topics. They are transdisciplinary in nature, involve complex phenomena, are laced with behavioral and social attributes and issues, with participants who have their own intentions, beliefs, etc. Framing of such research problems is critical to solving the right problems.

Transdisciplinary approaches go beyond simply including multiple disciplines on the research team. It is not sufficient for each discipline to "do its own thing" in the context of the overall endeavor. Instead, people have to appreciate and operate beyond the scope of their disciplinary competencies, trusting that people from other disciplines will help them contribute in this manner.

More specifically, transdisciplinary research needs to get past peer biases and pre-conceptions. Such research needs to promote the integration of insights and connection of ideas from diverse perspectives, interrogate issues from multiple viewpoints, and seek the benefits from alternative frameworks and approaches. This will foster innovation and creative thinking. If handled this way, then as a consequence, research into complexity and causality will bridge specialized representations of individual disciplines.

The workshop and this book also have implications for education. People often appreciate the transdisciplinary, complex, nature of the types of undertakings discussed in this book. However, they are typically ill-prepared to address such problems, in part due to being steeped in a particular disciplinary paradigm and a specific organizational context that constrains their perspectives regarding what is desirable and feasible.

This book can provide the basis for an educational program to better prepare people to deal with complex socio-technical systems. We suggest that any educational offering should have the following components:

- Broad framing of the topic with students from multiple disciplines
- Reading list drawn from several sometimes disparate disciplines
- Cases studies that illustrate the benefits of broad approaches
- Capstone projects that enable discovery and exercise of skills

This has implications for education at all levels, not just professional education. We can imagine educational programs ranging from ones targeted at senior executives to programs for K-12 school children. Although we certainly do not advocate that this book should be adopted for K-12 classrooms, we do think that appropriate experiences and exercises could be deigned to provide students with rich, multi-faceted views of the complexity and causality of the real world.

There are also policy implication of the workshop findings and of this book. Policy design and decision making should reflect the reality of complex socio-technical systems. Such systems are typically not amenable to command and control decision making. Instead, incentives and inhibitions need to be developed that motivate intelligent agents to self-organize in ways that benefit the overall system. These incentives and inhibitions need to be developed with attention paid to higher-order and possibly unintended consequences. The emergence machine and transplexity guide proposals by workshop participants provide two possible means of doing this.

OVERVIEW OF THE BOOK

In this section, we briefly summarize Chapters 2-22 to illustrate the flow of concepts, principles, models, methods and tools throughout the book.

Chapter 2: "Understanding Change In Complex Socio-Technical Systems: An Exploration of Causality, Complexity and Modeling" by William B. Rouse and Nicoleta Serban

This chapter elaborates the conceptual underpinnings needed to understand and influence change in complex socio-technical systems. The nature of causality is first addressed, followed by consideration of the nature of complexity. It is argued that, at least from a practical perspective, the difficulty in understanding causality increases as complexity increases. The possibility of influencing change is addressed in terms of concepts, principles and models for analysis and design in a range of domains or contexts.

Chapter 3: "The Causes for No Causation: A Computational Perspective" by Hussein A. Abbass and Eleni Petraki

This chapter begins by reviewing a few central concepts from philosophy and metaphysics. The discussion then centers on the causality of change in complex systems of systems and demonstrates that a counterfactual analysis of causality breaks down. The discussion then moves towards "change" and the separation between physical and perceptual elements. Three applications are presented as examples of the type of complexity we face in computational modeling of complex systems of systems. These three applications – covering story generation in linguistics, network centric operations in

defense and interdependency security problems - demonstrate how causal dependencies can be modeled, identified and extracted from a computational environment that mimics real-world complex systems of systems. The chapter concludes with a proposed model for controlling change in complex systems.

Chapter 4: “Fundamentals of Causality,” by Stephen Mumford and Rani Lill Anjum

The authors argue that philosophers aim to understand the world in its most basic, general and abstract way. Philosophers are not so much interested in the facts of what causes what, nor in what counts as good evidence of causation having occurred. Instead, philosophers attempt to get to the heart of the matter and consider what causation itself is. What does it consist in? Is causation a real feature of the world that grounds change? Is causation something that underlies its symptoms such as the regularities we often take to be evidence of causality? Is causation a primitive feature of the world or something we can analyze into more fundamental constituents? Philosophers might also be able to tell us how causation works: whether it is simple or complex, whether causal chains are transitive, whether causes must always precede their effects, whether causes necessitate their effects, and so on. Although there has been a settled, almost orthodox, view on these questions, recent decades have seen philosophers think through the fundamentals of causality anew. It is argued in this chapter, however, that the fresh perspectives hark back to a much older tradition, which perhaps constitutes a rediscovery of Aristotle.

Chapter 5: “Human Representation and Reasoning About Complex Causal Systems,” by Steven A. Sloman and Philip M. Fernbach

In this chapter, the authors characterize what is known about how people represent, reason about, and predict the behavior of complex systems. They focus on the dimension of human understanding where people go wrong – the cognitive foibles, tricks and shortcuts that determine how they understand complex systems – and on what they do well. They describe what human cognition brings to the table in the understanding of complex sociotechnical systems. They subscribe to the belief that human reasoning is "embodied" not just in an individual's own body but in physical systems that can include artifacts and other objects. The focus in this chapter, however, is to attempt to describe the contribution of the human mind to the study of sociotechnical systems. How the mind interacts with the relevant system will depend on the particulars of any actual case.

Chapter 6: “Effects of Context,” by Stephen Mumford and Rani Lill Anjum

This chapter explains how context bears on causality and emphasizes that it is not merely a minor consideration but, instead, of central importance. The same intervention in a situation can produce vastly different outcomes according to context. This is a matter that cannot be ignored, therefore, especially by those who decide strategy and policy within complex organizations susceptible to changing contexts where there are many potentially relevant contextual factors. The importance of context is explained by first describing some of the features of causality which is done in terms of polygeny and pleiotropy and also interconnectedness. The authors then proceed to explain some of the types of effects that follow from this view of causality, ranging from plain context-sensitivity, to

hypersensitivity, unintended consequences and antipathetic reactions. At the end, a position called causal particularism is advocated.

Chapter 7: "Management of Systemic Risks and Cascade Failures in a Networked Society," by Akira Namatame and Takanori Komatsu

This chapter uses network representations to address risks. The authors use a general framework of diffusion or contagion models to describe risk propagation in networks and investigate how network topology impacts risk propagation patterns. At the macroscopic level, systemic risk is measured as the fraction of failed nodes. They divide the discussion into two classes of diffusion. First, so-called progressive diffusion processes are discussed. Many diffusion processes are progressive in the sense that once a node switches from one state to another, it remains in that state in all subsequent time steps. The second class is non-progressive diffusion where, as time progresses, nodes can switch back and forth from one state to the other, depending on the states of their neighbors.

Chapter 8

TBD -- Snowden

Chapter 9: "Dancing with Ambiguity: Causality Behavior, Design Thinking, and Triple-Loop-Learning," by Larry Leifer and Martin Steinert

This chapter discusses a powerful methodology for innovation, "Design Thinking," that has emerged from engineering and design thinkers in Silicon Valley. It integrates human, business and technical factors in problem forming, solving and design. This human-centric methodology integrates expertise from design, social sciences, business and engineering. It creates a vibrant interaction environment that promotes iterative learning cycles driven by rapid conceptual prototyping. The methodology has proven successful in the creation of innovative products, systems, and services. Through courting ambiguity, the authors argue that we can let invention happen even if we cannot make it happen. We can nurture a corpus of behaviors that increase the probability of finding a path to innovation in the face of uncertainty. Emphasis is placed on a balance of the questions we ask, and the decisions made. A suite of application examples and research finding is used to illustrate the concepts in principal and in action."

Chapter 10: "How to Watch the Right Butterfly: Some Guidelines for the Design of Emergency Response Organizations," by Tim Haslett

This chapter proposes a methodology for assessing and redesigning emergency response organizations. The paper takes a multi-methodology approach and discusses a series of well-established theoretical frameworks to provide accessible and easy to understand processes for practicing managers. The discussion begins by highlighting the non-linear and catastrophic nature of civil emergencies as the basis for organizational design. The methodology proposed is sequential. The first stage uses Pepper's World Hypotheses as a means for assessing organizational responsiveness. The second stage applies Checkland's

CATWOE and stakeholder analysis as a means to applying the "wisdom of crowds" to organizational design. The third stage involves scenario planning using qualitative System Dynamics and causal loop diagrams. The fourth stage applies elements of Stafford Beer's Viable Systems Model to the process of environmental scanning. The fifth and final stage is a discussion of the need to build organizational learning into the adaptive capabilities of the organization.

Chapter 11: “Representations and Compressions,” by Michael R. Lissack

In this chapter the author discusses the business manager’s perception and understanding of change in complex markets and organizations. He criticizes the exclusive use of conventional and highly simplified ways (typical of many business schools) of representing causality as relationships between abstract labels or “representations” of complex causal mechanisms. Instead, to promote resilient responses to unpredictable change, he argues that managers should also focus on narratives, analogies, or “compressions” that preserve and reveal complex causal mechanisms. Using the Mori Uncanny Valley hypothesis from robotics, he provides crucial insights into how managers may dismiss the relevance of key signals during change in a market or organization, and for too long remain attached to an initial label-based model of the market or organization. He concludes that managers must appreciate the role of both compressions and representations when thinking about change.

Chapter 12 “Determining Causality and Dependency in Loosely Coupled, n-Dimensional Social Networks,” by Maris McCrabb

Social networks permeate our lives. The desire to understand them pervades much of social science today. This chapter offers an empirically sound method for analyzing causal and dependency relationships among the people, places, things, and concepts that flow within and between social networks. A particular emphasis of this approach is modeling and analyzing the connections between social networks and the physical networks that enable social networks. Most social networks lack a fixed organizing principle or any discernable, formal structure. This results in a loose coupling of elements within or between networks. It also makes identification of boundary layers difficult. Further, the dimensionality of loosely coupled networks can grow enormously. The approach described here, called Williamsburg, addresses three issues in social network analysis: loose coupling of networks, dimensionality, and the need to test empirically the analytic findings from our approach to social network analysis.

Chapter 13: “General Systems Performance Theory and Its Application to Understanding Complex System Performance,” by George V. Kondraske

This chapter describes efforts to find a generalizable method for predicting the performance of complex systems in which humans participate. The author discusses General Systems Performance Theory, which aims to provide a common conceptual basis for defining, measuring, and analyzing all aspects of system performance, and identifying reasons for the success or failure of activities performed within the system. A methodology called Nonlinear Causal Resource Analysis is described, by which an

expected level of complex system performance is predicted at a high level from the amount of resource available vs. amount of resource demanded from each contributing performance resource at a lower level. The key to the prediction lies in identifying the limiting performance resource for a particular participant or group of participants on a particular activity. Tests of the methodology that illustrate its predictive power are drawn from the fields of automobile driving and surgical performance. The logic underlying the approach depends in part on reductionism but, paradoxically, the combination rules lead to some successful predictions of complex human-system activity.

Chapter 14: "Advances in Statistical Analytical Strategies for Causal Inferences in the Social and Behavioral Sciences," by David Chan

This chapter focuses on applying statistical advances to "causality of change" in terms of analyzing correlational/observational data in two broad causal inferential contexts. The first context refers to modeling causal relationships between constructs, specifically on relationships that go beyond the "bivariate prediction paradigm". Mediation analyses, interaction analyses, combination of interactions and mediations, and structural equation modeling are discussed. The second context refers to modeling the causes of changes over time. In this context, the author explicates the fundamental questions on changes over time and illustrates the limitations of traditional techniques for analyzing changes over time. Latent variable approaches to modeling changes over time are also discussed.

Chapter 15, "Causal Inference and Heterogeneity Bias In Social Science," by Yu Xie

Because of population heterogeneity, causal inference with observational data in social science may suffer from two possible sources of bias: (1) bias in unobserved pretreatment factors affecting the outcome even without treatment; and (2) bias due to heterogeneity in treatment effects. Even when we control for observed covariates, these two biases may occur if the classic ignorability assumption is untrue. In cases where the ignorability assumption is true, "composition bias" can occur if treatment propensity is systematically associated with heterogeneous treatment effects.

Chapter 16: "Entropy: A Unifying Path for Understanding Complexity in Natural, Artificial and Social Systems," by Constantino Tsallis

This chapter addresses *energy* and *entropy,* basic concepts in thermodynamics and elsewhere. The concept of energy emerged in mechanics, the branch of physics that studies the motion of bodies and their causes. In contemporary physics, it appears in classical, relativistic and quantum mechanics. The concept of entropy emerged quite later than that of energy. Rudolf Julius Emmanuel Clausius introduced this concept around 1865 in order to further understand the roles of heat and work in thermodynamics. A decade later, Ludwig Eduard Boltzmann gave an interpretation of entropy in terms of the microscopic world – atoms, molecules, and their motion -- whose existence was at the time very controversial. This chapter discusses various applications of non-additive entropy and its associated non-extensive statistical mechanics to understanding complex systems.

Chapter 17: "Plasticity and Causal History in Complex Adaptive Systems: The Case of the Human Brain," by David F. Batten

This chapter explores and reviews progress with the concepts of plasticity, rigidity and causal history in brain research and related fields. Extensive use is made of papers and books in neuroscience and related fields (e.g. psychiatry, psychology, psychophysiology), as well as meeting proceedings and special issues of leading journals. The goal of the chapter is to show that the human brain is plastic and that it contains various feedback loops that affect the ways we behave. Processes of circular causality (i.e. upward and downward causation) govern our brain's functioning. What we experience can alter the detailed neuronal structure of our brain and, in turn, that changed neuronal structure can affect what we feel, believe or do in the future. A deeper understanding of plasticity, rigidities and feedback systems may provide a clearer picture of the causal and influence networks evolving within the brain – and how they shape our state(s) of mind.

Chapter 18: "Towards Safe Information Technology in Health Care," by Jos Aarts

Health information technology is widely expected to increase patient safety and reduce medical errors. However, widespread implementation of health IT makes it evident that health information technology has become part of a complex sociotechnical system that is health care. Design and implementation of health IT may result in a failure; in some cases, health information technology can lead to adverse events instead of mitigating them. In this chapter, the author outlines the complexity of health information technology as a part of a sociotechnical system, describes two failures at different organizational levels and presents a model of how risks tend to occur. Unfortunately there is mainly anecdotal knowledge about health information technology failures and potential adverse effects. Therefore the author suggests how, as a first step, proper and mandatory reporting can lead to better knowledge of failures of health information technology as part of a sociotechnical system and improve deployment in the coming years.

Chapter 19: "Making Complexity Work in Practice," by Patrick Beautement

This chapter addresses causality in practice and explains the characteristics of practice. It then examines how, in social contexts, the complex networks of vested interests, power groupings, dynamic influences and community and cultural tensions can be identified and managed, leading to there being perceptions of successful outcomes. Key to this is recognizing how 'success' would be seen from the various perspectives and viewpoints and understanding, practically, the opportunities and limitations for intercepting and engaging with these complex motivations - even though some appear to be contradictory or even incompatible. The chapter describes a 'Landscape', inspired by complexity science, which is used to contrast two urban situations and to show how some of the outcomes and their consequences can be explained in causal terms. It concludes by suggesting developments needed to provide practitioners with a systematic approach to putting 'complexity thinking' to work in practice.

Chapter 20: "Causality and the Law," by Ian Freckelton

This chapter analyses, in a broad and international sense, dilemmas that confront the law in grappling with causality. Inevitably, the law does so on the basis of assistance rendered and perspectives provided from other disciplines. In addition, it undertakes its functions, applying policy considerations to its task. Sometimes these are explicitly articulated; on other occasions they are not. First, the author identifies how questions of causality arise for the law and scrutinizes a number of major tests of causality. He then identifies dilemmas that have arisen for findings of causality for the law in the context of potential breaks in the chain of causation and explores the intrusion of policy considerations which in some situations have been determined by the courts as negativing causation and thereby compensability. The chapter concludes by identifying a series of factors in expert evidence that can result in problematic causality determinations. The author argues that coherent approaches to causality remain elusive for the law, and that policy factors in terms of whether liability should be imposed upon particular categories of defendants play a major role in causation law, which often depends in courts' decisions regarding expert evidence.

Chapter 21: "Naturalistic Investigations and Models of Reasoning about Complex Indeterminate Causation," by Robert Hoffman, Gary Klein and Janet Miller

This chapter focuses on causal reasoning. The emphasis is on reasoning about events that are indeterminate and complex. The authors distinguish reasoning about complex human activities from reasoning about physics problems (for instance), which have knowable, single, and definite answers. Sociotechnical systems produce complex and indeterminate situations: Answers are rarely simple and are always tentative. Sociotechnical systems have to be understood at the level of "macrocognition," or at the level of analysis of activities such as problem detection, planning, and decision making. The authors distinguish such cognitive phenomena from those that are the concern at the "microcognition" level, which focuses on such things as short-term memory access and millisecond-level shifts of attention. Appropriate to its level of analysis, the macrocognition paradigm is empirically grounded in studies of "naturalistic decision making," such as the ones described in this chapter.

Chapter 22: "Information, Knowledge and Systems Management Approaches for a New Global Reserve Currency," by Mario W. Cardullo and Andrew P. Sage

The global financial system appears to be heading for a new crisis, triggered in large part by growing and unsustainable levels of global debt. Reserve currencies are an essential element of the world's current financial infrastructure, and are widely recognized for their role in facilitating international transactions. History has taught us that such currencies are also quite transient, being subject to adjustments and changes as economic conditions evolve over time. The United States dollar now serves as the world's de facto reserve currency. However, this is unlikely to continue unchallenged and unchanged into the future. The G20 and the International Monetary Fund appear to be now considering a reserve currency, such as the Special Drawing Rights, which is obtained through participation of many currencies. The major question is not what will become the new global reserve currency, but how

this new currency will be managed. One of the critical issues associated with this currency management effort is that of determining the information systems architecture that will be required, including whether an associated Service Oriented Architecture would be helpful in managing this new global currency. An extremely important element in this currency determination activity is a strong governance protocol that all the governments and sovereigns will accept and comply with. Otherwise any new global reserve currency, regardless of whether it is associated with a major information systems architecture foundation, will likely be unsustainable. These issues are examined in this chapter.